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Pup production of Northwest Atlantic grey seals in the gulf of St. Lawrence and along the Nova Scotia Eastern Shore

La production de phoques gris de l'Atlantique Nord-Ouest dans le golfe du Saint-Laurent et le long de la côte est de la Nouvelle-Écosse

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ABSTRACT

In the Gulf component of the Northwest Atlantic grey seal population animals are born on the pack ice in the Gulf of St. Lawrence as well as on small islands in the Gulf and along the east coast of Nova Scotia. In 2007, visual strip transect surveys were flown over the whelping patches on the ice in the Gulf of St. Lawrence and counts were completed at islands in the Gulf and along the Nova Scotia Eastern Shore. Aerial searches for grey seal pups were also conducted along the south and southwest coasts of Newfoundland and Anticosti Island. Where possible counts were corrected for the proportion of pupping completed when the survey was completed. Changes in age specific durations resulted in a 17% change in pup production estimates. Total pup production, rounded to the nearest thousand is estimated to be 13,000 (SE=600) animals. The proportion of pups born on the ice has declined from over 95% in the mid-1980s to about 30% in 2007.

RÉSUMÉ

Au sein de la composante du golfe de la population de phoques gris de l'Atlantique Nord-Ouest, les petits naissent sur la banquise dans le golfe du Saint-Laurent, ainsi que sur les petites îles du Golfe et le long de la côte est de la Nouvelle-Écosse. En 2007, des recensements aériens visuels au moyen d'une grille de transects ont été effectués au-dessus des aires de mise bas sur les glaces du golfe du Saint-Laurent, tandis que les bébés phoques étaient dénombrés dans les îles du Golfe et de la côte est de la Nouvelle-Écosse. Des recherches aériennes de bébés phoques gris ont aussi été entreprises le long des côtes sud et sud-ouest de Terre-Neuve et de l'île d'Anticosti. Chaque fois que possible, leur nombre a été corrigé à la fin du relevé en fonction de la proportion de mises bas achevée. Les changements de la durée liés à l'âge ont donné lieu à une modification de l'estimation de la production de petits de l'ordre de 17 %. La production totale de bébés phoques, arrondie au millier le plus près, serait de 13 000 bêtes (écart-type de 600). La proportion de petits nés sur la banquise a diminué, passant de plus de 95 % au milieu des années 1980 à environ 30 % en 2007.

INTRODUCTION

The Northwest Atlantic grey seal (*Halichoerus grypus*) population is normally divided into two groups for management considerations: a Sable Island and a non-Sable Island component. Using pup production as an index of population size and trends, pup production on Sable Island has increased rapidly since the 1970's, from less than 2,000 animals in 1975 to over 25,000 pups in 1997 (Bowen et al. 2003) for an annual rate of increase of 12.8%. Estimates of pup production from surveys completed in 2004, indicated that numbers had continued to increase to 41,500 (SE=4,381), but that the rate of increase had declined to about 7%(Bowen et al. 2007).

Less is known about the non-Sable Island component of the Northwest Atlantic grey seal population. This component has traditionally been dominated by pups born on the ice in the Gulf of St. Lawrence and has been often been referred to as the Gulf component. Smaller whelping colonies that are included in this Gulf group are found on small islands at Amet Island, Deadman Island, and along the Nova Scotia eastern shore (Mansfield and Beck 1977). A new colony was discovered on Hay Island in 1993 by J. Conway (DFO-Halifax)(Fig. 1).

Pup production in the Gulf component has been more variable, ranging from a low of 5,436 (SE=672) in 1984, increasing to 11,100 (SE=1,300) by 1996, but since then subsequent surveys indicated that pup production has varied between 6,100 (SE=900) and 15,600 (SE=1,200) between 2000 and 2004(Hammill et al. 2005,2007).

Here we provide a new estimate of Gulf pup production from aerial surveys and island counts completed in January-February 2007.

MATERIALS AND METHODS

Reconnaissance surveys

Reconnaissance aerial surveys were flown in the southern Gulf and along the Nova Scotia Eastern Shore at an altitude of 500 feet from a helicopter during December 2006-February 2007 (Fig. 2). Additional low-altitude flights were made using the DFO enforcement Super King Air aircraft in January along the south and west coast of Newfoundland (Fig.3), and in February around the coast of Anticosti Island (Fig. 4).

There have been some reports from fishermen that new colonies have formed to the west of Halifax and around the southern shore of Nova Scotia. A questionnaire was designed to collect information from fishermen on the location and size of grey seal breeding sites around Nova Scotia, outside of the traditional areas. The following questions were asked: where have you seen grey seal pups; when did you see them; how many did you see (<10, 10-100 or >100); what type of habitat where they seen on; are there sites where you use to see pups but no longer do;
Based on the results of the questionnaire, a helicopter survey was conducted along the coastline between Brier Island (44° 16' 00" N - 66° 21' 57" W) and Cape North (46° 53' 04" N - 60° 30' 21" W). All of the sites identified by the questionnaire as potential grey seal breeding sites were surveyed (Fig. 5).

Strip transect surveys

Visual strip transect aerial surveys were flown at an altitude of 61 m by helicopter to estimate the number of pups on the ice. Observers seated in the left and right rear seats counted all seals within a measured 50 m strip on each side of the aircraft. The strip was delimited prior to the surveys by placing tape marks on the windows while hovering at an altitude of 61 m over a measured distance marked out on the ice. Tape marks were also placed on the window to denote the horizon and the outside of the helicopter skid to aid the observer in maintaining a constant position. Following the survey, strip widths were checked again to confirm the areas surveyed.

The data were analysed using the methods outlined in Hammill *et al.* (1992). Survey strata were defined based on homogeneous transect spacing. For each group a weighting factor k_i was calculated as:

$$k_i = S_i / W_i \qquad (3)$$

where S_i is the transect spacing (km) for the i^{th} group and W_i is the transect width (km) for the i^{th} group.

The estimated number of pups for the i^{th} survey is

given by:
$$N_i = k_i \left[\sum_{j=1}^{J_i} x_j \right] \qquad (4)$$

where x_j is the number of seals counted on a transect and J_i is the number of transects in the i^{th} survey.

The error variance was calculated based on the serial difference between transects (Cochran 1977; Kingsley *et al.* 1985) using:

$$V_i = \frac{k_i(k_i-1)J_i}{2(J_i-1)} \sum_{j=1}^{J_i-1} (x_j - x_{j+1})^2 \qquad (5)$$

If transect spacing changed the estimate of the number of animals became:

$$N_i = k_i \left[x_{i1}/2 + \sum_{j=2}^{J_i-1} x_{ij} + x_{iJ_i}/2 \right] \qquad (6)$$

and the variance estimate became:

$$V_i = \frac{k_i(k_i-1)}{2} \sum_{j=1}^{J_i-1} (x_j - x_{j+1})^2 \qquad (7)$$

The estimate for the total population and its variance estimate became:

$$N = \sum_{i=1}^{I} N_i \qquad (8)$$

$$V = \sum_{i=1}^{I} V_i \qquad (9)$$

where I is the number of groups of transects.

Island counts

Pupping also occurs on several islands in the area. These were counted using several different techniques. At Amet Island, animals pup on the narrow beaches and on the ice that is caught on the reefs around the island. A total count was obtained by standing on top of the island, which is about 6 m above sea level, and counting seals around the island. At Henry Island, pupping occurs along narrow beaches along the south and west sides of the island as well as the more accessible east side. Animals were counted from the air by helicopter hovering at 20 m and moving along the beach about 20 m offshore, or by walking the beach and obtaining multiple counts from different observers. At Oak, Pictou and Deadman Islands, pupping occurs on beaches around the islands. The helicopter landed at these sites, and two counters walked along the seal beaches, from one end of the colony to the other and back. Thus each counter obtained two counts of the number of pups on each beach. The final count was the average of the four counts. At Hay Island, vertical poles were set in the ground at 50 m intervals, setting up a series of transects along the island. Counters moved from one end of the island to the other and back. The count for each transect was the average of these two counts. These were summed over the transects. At White Island and Bowen's Ledge, all pups were tagged to provide a total count.

Birth ogive

Non-Sable Island Northwest Atlantic grey seals begin pupping on the islands in December and births continue until early February. The majority of births, particularly of ice breeding animals, occur in January. Aerial survey estimates were corrected to account for births that occurred after counts were completed by modelling the distribution of births over the period of the survey. The model assumes that births follow a normal distribution and uses the change in the proportion of pups of different ages as the season advances to develop the birthing ogive (details described in Stenson *et al.* 2003). Estimates of the number of pups in each concentration can then be corrected for pups born after the survey was flown by:

$$N_i = N_{uncor} / P_i \qquad \textbf{(1)}$$

where:

N_{uncor} = the uncorrected estimate for survey *i*;

P_i = the proportion estimated to have been born prior to survey *i*.

The estimates of N_{uncor} and P_i are independent and therefore the error variance of the quotient is given by (Mood *et al.* 1974):

$$V_i = N_{uncor}^2 \times V_p / P_i^4 + V_n / P_i^2 \qquad (2)$$

where:

V_p = the variance in the proportion estimated to have been present prior to survey *i*;

V_n = the variance in the uncorrected estimate for survey *i*.

Pups were assigned to one of three distinct age-related categories based on a combination of morphometric and pelage features to model the distribution of births (Bowen *et al.* 2003). Stage duration data, referred to as "Old" were obtained from Bowen *et al.* (2003). New data, suggesting a change in the stage durations (W.D. Bowen, DFO, Dartmouth, N.S. pers. comm.) was also used to correct the survey counts and is referred to as "New".

Stage 1- animals very thin, movements uncoordinated, and the fur has a yellowish hue from the placental fluids (Old: Mean duration=3.4 days, SE=0.91: New: 3.0, SE=0.64);

Stage 2- animals are thin, although they are beginning to show signs of fattening, a distinct neck is still visible, movements are more coordinated and the pelage no longer has a yellowish hue (Old: Mean duration=4.4 days, SE =1.29; New- Mean=3.0, SE=0.65)

Stage 3- the fur is white in colour and the animals have become so fat that a distinct neck is no longer discernable (Mean duration=12.1 days, SE =2.77; New Mean=11.8, SE=2.53).

The study area was surveyed repeatedly and the change in the proportion of pups in each of the age dependent categories was noted.

RESULTS

Reconnaissance surveys

The areas where pupping is known to occur in Northumberland Strait, and around Cape Breton Island were searched and assessed frequently from December until February. The exception is the Deadman Island area which was surveyed only once. This survey also included a survey around Brion Island to the north of the Magdalen Islands. No pups were seen at Brion Island. In December, the reconnaissance surveys covered the Northumberland Strait area, Henry Island on the west coast of Cape Breton Island and between Sydney on the east coast of Cape Breton Island along the coast to White Island/Bowen Ledge area on the Nova Scotia Eastern Shore. On 8 January, a flight was made to the Miramichi area, but no pups were seen. This area was surveyed again on 22 January, including the west coast of Prince Edward Island, as well as the coast of New Brunswick from the Kouchibouguac Park area north to Baie des Chaleurs. Three fat whitecoats were seen on the beach at the park. On 11 January, the east coast of Nova

Scotia was surveyed by helicopter between Halifax and Pt Hawkesbury, including the offshore Islands, but no pups were observed except at the known colonies of White Island/Bowen Ledge just off Ecum Secum (Fig.1). On 13 February, a reconnaissance flight was made around Anticosti Island (Fig. 4). Approximately 10 pups were seen, but no accurate count was made. No grey seal pups were seen during the aerial searches around Newfoundland on 23 January, despite ideal sighting conditions and relatively benign weather conditions. These results accord with several similar aerial searches conducted in previous years in the same areas (J. Lawson, unpubl. data). There is a summering group of several hundred grey seals in the Grand Barachois on the French island of Miquelon (near St. Pierre) on the south coast of Newfoundland (Fig. 3). Based on brands and visible flipper tags, a portion of these seals return to Sable Island to breed during the winter, even though they spend their summers hauled out in the Barachois (J. Lawson, unpubl. data). A number of fishermen and residents of the island of St. Pierre and Miquelon have been questioned, but none have indicated the presence of white-coated seal pups (grey or harp seals) in the winter (Lawson unpublished data).

Between January 2005 and October 2006, 149 fishermen were interviewed either by phone (N=83) or in person (N=66). The data collected from the questionnaire provided a reasonable coverage of the Nova Scotian shore from Cape North to Yarmouth. According to the questionnaire, the largest grey seal breeding colonies were located at Noddy Island, Cape Sable, inshore islands off Ecum Secum and Hay Island (Fig 1). These was areas were surveyed over 4 days, 11th, 28th, 30th and 31st January 2007. The survey identified two new breeding colonies: Noddy Island, and Flat Island, and three colonies that been known from previous work: White Island, Bowen's Ledge and Hay Island.

There was little ice cover in the region. Visual strip transect surveys were flown the 24, 29, and 30 January (Fig. 6; Table 1). Additional surveys were not flown because the ice was quite thin and there appeared to be some ice destruction. During the third survey there appeared to have been a loss of animals. During each survey, the entire patch was surveyed in a single day. On 24 January, transects were divided into 4 strata, with a line spacing of 1 or 4 minutes of longitude between lines (Fig. 3). A total of 73 pups were counted along 25 transects, resulting in an estimate of 1,292 (SE=294)(Table 1). On 29 January, the whole area was surveyed as a single stratum with a line spacing of 4 minutes of longitude. A total of 67 pups were counted along 19 transect lines resulting in an estimate of 3,705 (SE=1,104) animals. On 30 January, the whole area was again flown as a single stratum with a line spacing of 4 minutes of longitude between transects. A total of 44 pups were counted on the 19 transect lines resulting in an estimate of 2,273 (SE=604) animals.

Stage surveys were completed over pups on the ice as well as the larger breeding colonies (Tables 2, 3). For the ice in Hillsborough Bay and in Northumberland Strait the proportion of births varied between 0.34 (SE= .08) and 0.74 (SE=0.06), using the Old stage durations (Table 4). Estimated pup production on the ice after correcting for the proportion of births that had occurred was 3,746 (SE=1,243), 5,124 (SE=1,707) and 3,082 (SE=858) for the surveys flown 24, 29 and 30 January respectively (Table 4). If the New stage durations are used, then the proportion of pupping that had occurred by the time that the surveys had been flown varied from 0.21 to 0.60 (Table 4). Estimated pup production was 6,249 (SE=2,514), 6,613 (SE=2,327) and 3,819 (SE=1,125) for the surveys flown 24, 29 and 30 January respectively (Table 4).

Pups counts were also conducted at Amet, Henry, Deadman, Oak, Pictou, Hay, and White Islands, Bowen's Ledge, Noddy and Flat Islands (Fig.1) (Table 5). A total of 8,850 pups were counted on the different Islands, including the three animals seen on the beach in Kouchibouguac park, approximately 10 animals seen on Anticosti Island, 135 at Noddy Island and 69 on Flat Island (Table 6). This represents a minimum count, since some of the islands were only visited once, which does not allow development of a correction curve.

Combining the strip transect survey and island counts and correcting for births after surveys were flown results in a total pup production of 12,319 (SE=714), using the Old stage information. If New stage duration data are used, then the estimate increases to 14,436 (SE=1,079) (Table 6). Combining the two estimates results in a pup production estimate of 9,948 (SE=594) in the Gulf, and 3,017 (SE=40) along the Eastern Shore, for a total non-Sable Island pup production of 12,964 (SE=595) in 2007.

DISCUSSION

The method used to evaluate the pup production of Gulf grey seals has evolved over time since assessments began in the early 1980s. Early studies used mark-recapture methods based on live recaptures at Sable Island of marked animals in the year of their birth, or by the recovery of marked animals from shot samples in the same or subsequent years to marking (Hammill *et al.* 1998). At that time, all pups born on Sable Island were tagged, so a tagged animal could be distinguished between Sable Island and the Gulf, and an unmarked animal was assumed to come from the Gulf herd. This was a reasonable assumption, since very few pups were born outside of the Gulf or on islands at the time (see below). In the early 1990s, the marking programme at Sable Island ended, which meant that it was not possible to determine if an unmarked pup was from the Gulf or the Sable Island component. Fewer opportunities arose for the recovery of marked animals as well. This led to the application of aerial survey techniques, similar to the approaches used to assess harp seals (Stenson *et al.* 2003), where extensive reconnaissance is carried out to detect all concentrations, systematic surveys are flown to estimate the number of animals present on the ice, and a parallel set of surveys are completed to work out the proportion of pupping that has occurred when the survey was flown (Hammill *et al.* 2007). Since the early 1990's a series of winters with poor ice conditions has caused some changes in pattern of pupping observed in the Gulf and has also resulted in changes in the assessment technique. Prior to 1996, less than 5% of the pups were born on islands within and outside of the Gulf, with 95% of the pups born on the ice. Due to a series of winters with poor ice conditions, particularly since 1997, the proportion of pups born on the ice declined to approximately 80% of production during the assessments of 1997, 2000, and 2004 (Fig. 6)(Hammill *et al.* 2007), then declined further to approximately 30% of total Gulf production in 2007. New colonies have also appeared at Hay Island (1993), Henry Island (1997), Oak Island (2007), Pictou Island (2007 assessment, but reports of some pupping since 1997), Kouchibouguac National Park (2007) and Anticosti Island (2007). The presence of pups at Anticosti Island was particularly surprising, since animals are thought to leave the northern Gulf during winter (e.g., Goulet *et al.* 2001). However, in most years there is considerable ice around Anticosti Island and conditions are more severe. If mild winters continue, then more extensive reconnaissance effort will be needed throughout the northern Gulf. Nonetheless, as the proportion of the population whelping on land has increased, new approaches have been developed to count animals

on the islands, and in 2007, repeated visits were made to the larger islands to correct counts for pupping.

The repeated visits to the larger islands allowed some comparison between actual counts made on different occasions and the corrected counts after taking into account the proportion of pupping that had been completed by the time a count had been completed. At Hay, Henry and Pictou Islands, there was good agreement on most occasions between the predicted number of pups and the actual number of pups counted. However, marked discrepancies were observed between the predicted number of pups from an early survey at Amet Island and what was observed at later surveys, and a decline was observed in late counts at Henry and Hay Islands. For the ice survey, there was good agreement between pup production estimates from surveys flown on 24 and 29 January, particularly when the New stage duration data were used. However, fewer animals were evident from the 30 January survey, suggesting that animals were lost from the thin ice, or the estimate is simply negatively biased.

Applying corrections to the pup count and survey estimates assumes that the stage duration is known, the distribution of births follows a normal distribution and there is no emigration from the area. Recent evidence from Sable Island indicates that the duration of the stages does change. Incorporating these changes into the Gulf counts increased the population estimates by 17%. Unfortunately, little is known about factors affecting stage durations, whether it might be colony-specific, seasonally or environmentally dependent. Collecting stage duration data from the ice is difficult, and may not be feasible, particularly in poor ice years. It may be possible to collect more data from different colonies and this needs to be investigated. In looking at the distribution of births, the assumption of a normal distribution appears to be reasonable. The marked discrepancy observed between an early count and two later counts at Amet Island are likely due to the loss of animals from breaking of ice on the reefs or abandonment. This island is hunted, and animals are easily disturbed. At Henry Island, there was a decline in the number of animals on the island after a storm, which washed away many pups along the western and southern side of the island, this late count was also discarded.

The Sable Island and Gulf grey seal colonies have had very different population trajectories. These differences likely result from the higher culling and scientific harvests in the Gulf (Stobo and Zwanenburg 1990; Hammill *et al.* 1998), and the higher mortality rates experienced by animals in the Gulf of St. Lawrence. Pup production in the Gulf appears to have fluctuated substantially between surveys (Table 7). This fluctuation results from variable ice conditions, particularly changes observed since the early 1990s (Fig. 6). During surveys completed in 1997, large numbers of pups born on the ice were forced up along the north shore of Nova Scotia east of Pictou Island, particularly around Cape George. Although it could not be quantified, mortality was expected to be high. At the time, the majority of pups born in the Gulf were born on the ice. Since then, new island colonies have appeared, likely in response to the poor ice conditions (Fig. 7).

The grey seal is the only species that regularly breeds on land or on ice. The appearance of new colonies underlines how adaptable this species appears to be. On the small islands in the area, the colonies are relatively isolated and little disturbed. However, other colonies such as Oak Island are easily accessible. Visits from snowmobiles and all terrain vehicles are frequent and disturbance can be high, resulting in abandonment of pups by adults. In these cases pup mortality might be high and little expansion in a colony such as this would be expected.

Pupping in the Gulf begins in late December in areas such as Amet Island and continues into February. For the ice-breeding component, late stages (ragged jackets, beaters) are rarely encountered and survey efforts focused on assessing the proportion of stages 1-3 (newborn, thin and fat whitecoat), before animals left the ice because of destruction or emigration. On island breeding colonies there is the potential for a much longer use of the sites. This may mean that taking into account emigration in the pup ogive corrections to the survey counts will become more important in future assessments.

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LITERATURE CITED

Boskovic, R., K.M. Kovacs, and M.O. Hammill. 1996. Geographic distribution of mitochondrial DNA haplotypes in grey seals *Halichoerus grypus*. Can. J. Zool. 74:1787-1796.

Bowen, W.D., R.A. Myers and K. Hay 1987. Abundance estimation of a dispersed, dynamic population: hooded seal (*Cystophora cristata*) in the Northwest Atlantic. Can. J. Fish. Aquat. Sci. 44:282-295.

Bowen, W.D., J. McMillan and R. Mohn. 2003. Sustained exponential population growth of grey seals at Sable Island, Nova Scotia ICES J. Mar. Sci. 60:1265-1274.

Bowen, W.D., J.I. McMillan and W. Blanchard. 2007. Reduced Population Growth Of Gray Seals At Sable Island: Evidence From Pup Production And Age Of Primiparity. Marine Mammal Science, 23(1): 48–64

Cochran, W.G. 1977. Sampling techniques. 3rd Ed. Wiley, New York, NY. 428 p.

Goulet, A.-M., M.O. Hammill and C. Barrette. 2001. Movements and diving activities of grey seal females (*Halichoerus grypus*) in the Gulf of St Lawrence, Canada. Polar Biology 24:432-439.

Hammill, M.O., G.B. Stenson, and R.A. Myers. 1992. Hooded seal (*Cystophora cristata*) pup production in the Gulf of St Lawrence. Can. J. Fish. Aquat. Sci. 49:2546-2550.

Hammill, M.O., G.B. Stenson, R.A. Myers and W.T. Stobo. 1998. Pup production and population trends of the grey seal (*Halichoerus grypus*) in the Gulf of St Lawrence. Can. J. Fish. Aquat. Sci. 55:423-430.

Hammill, M.O., J.-F. Gosselin. 2005. Pup production of non-Sable Island grey seals, in 2004. DFO Can. Sci. Advis. Sec. Res. Doc. 2005/033.

Hammill, M.O., J.F. Gosselin and G.B. Stenson. 2007. Changes in abundance of grey seals in the NW Atlantic. Pages 99-115. *In* T. Haug, M. Hammill and D. Olafsdottir. (eds). Grey seals in the North Atlantic and the Baltic. NAMMCO Scientific publication 6. 227 p.

Kingsley, M.C.S., I. Stirling, and W. Calvert. 1985. The distribution and abundance of seals in the Canadian high Arctic. Can. J. Fish. Aquat. Sci. 42:1189-1210.

Mansfield, A.W. and B. Beck. 1977. The grey seal in eastern Canada. Dept. Environ., Fish. And Mar. Serv. Tech. Rep. No. 704. 81 pp.

Mood, A. M., F. A. Graybill and D. C. Boes. 1974. Introduction to the Theory of Statistics, 3rd Ed. McGraw-Hill, Toronto. Xvi, 564p.

Myers, R.A., M.O. Hammill, and G.B. Stenson. 1997. Using mark-recapture to estimate the numbers of a migrating population. Can. J. Fish. Aquat. Sci. 54:2097-2104.

Stenson, G.B., R.A. Myers, I.-H. Ni, W.G. Warren and M.C.S. Kingsley. 1993. Pup production of harp seals, *Phoca groenlandica*, in the northwest Atlantic. Can. J. Fish. Aquat. Sci. 50:2429-2439.

Stenson, G.B., Rivest, L.-P., M.O. Hammill, J.-F. Gosselin, and B. Sjare. 2003. Estimating Pup Production of Harp Seals, *Phoca groenlandica*, in the Northwest Atlantic. Marine Mammal Science 19:141-160.

Stobo, W.T. and K.C.T. Zwanenburg. 1990. Grey seal (*Halichoerus grypus*) pup production on Sable Island and estimates of recent production in the Northwest Atlantic. Pages 171-184 *in* W.D. Bowen (ed). Population biology of sealworm (*Pseudoterranova decipiens*) in relation to its intermediate and seal hosts. Can. Bull. Fish. Aquat. Sci. No 222. 306 p.

Table 1. Number of pups counted on north-south transects during visual surveys of Northumberland Strait during January 2007. Different strata or surveys flown on different days are separated by a blank line

Date	Trans	Start latitude (deg/min)		Longitude (deg/min)		Stop latitude (deg/min)		Space (min. long.)	Total pups	Adj. pups
07-01-24	1	45.00	52.30	61.00	56.00	45.00	53.00	4.00	0	0
07-01-24	2	45.00	52.70	62.00	0.00	45.00	51.00	4.00	0	0
07-01-24	3	45.00	52.00	62.00	4.00	45.00	48.00	4.00	0	0
07-01-24	4	45.00	46.00	62.00	8.00	45.00	50.00	4.00	0	0
07-01-24	5	45.00	44.00	62.00	12.00	45.00	49.00	4.00	1	1
07-01-24	6	45.00	48.60	62.00	16.00	45.00	42.70	4.00	0	0
07-01-24	7	45.00	46.00	62.00	20.00	45.00	41.00	4.00	0	0
07-01-24	8	45.00	40.00	62.00	24.00	45.00	48.00	4.00	1	1
07-01-24	9	45.00	39.00	62.00	28.00	45.00	49.80	4.00	3	1.5
07-01-24	9	45.00	39.00	62.00	28.00	45.00	49.80	1.00	3	1.5
07-01-24	10	45.00	39.00	62.00	29.00	45.00	50.00	1.00	12	12
07-01-24	11	45.00	50.00	62.00	30.00	45.00	39.50	1.00	25	25
07-01-24	12	45.00	39.80	62.00	31.00	45.00	50.00	1.00	7	7
07-01-24	13	45.00	52.20	62.00	32.00	45.00	39.70	1.00	3	1.5
07-01-24	13	45.00	52.20	62.00	32.00	45.00	39.70	4.00	3	1.5
07-01-24	14	45.00	40.00	62.00	36.00	45.00	52.00	4.00	4	4
07-01-24	15	45.00	44.00	62.00	40.00	45.00	55.00	4.00	0	0
07-01-24	16	45.00	56.00	62.00	44.00	45.00	45.00	4.00	0	0
07-01-24	17	45.00	45.80	62.00	48.00	45.00	56.70	4.00	0	0
07-01-24	18	46.00	8.00	62.00	59.00	46.00	4.00	1.00	0	0
07-01-24	19	46.00	4.00	63.00	0.00	46.00	8.00	1.00	2	2
07-01-24	20	46.00	9.00	63.00	1.00	46.00	4.00	1.00	1	1
07-01-24	21	46.00	2.00	63.00	2.00	46.00	9.00	1.00	9	9
07-01-24	22	46.00	7.90	63.00	3.00	46.00	0.00	1.00	2	2
07-01-24	23	46.00	0.00	63.00	4.00	46.00	10.00	1.00	1	1
07-01-24	24	46.00	10.00	63.00	5.00	46.00	0.00	1.00	2	2
07-01-24	25	46.00	0.00	63.00	6.00	46.00	6.00	1.00	0	0
07-01-29	1	45.00	41.00	61.00	34.00	45.00	54.00	4.00	0	0
07-01-29	2	45.00	39.00	[illegible].00	38.00	45.00	55.00	4.00	1	1
07-01-29	3	45.00	56.00	61.00	42.00	45.00	39.00	4.00	1	1
07-01-29	4	45.00	40.00	61.00	46.00	45.00	52.00	4.00	7	7
07-01-29	5	45.00	47.00	61.00	50.00	45.00	40.00	4.00	4	4
07-01-29	6	45.00	53.00	61.00	54.00	45.00	47.00	4.00	13	13
07-01-29	7	45.00	55.00	61.00	58.00	45.00	53.00	4.00	7	7
07-01-29	8	45.00	48.00	62.00	2.00	45.00	55.00	4.00	1	1
07-01-29	9	45.00	55.00	62.00	6.00	45.00	47.00	4.00	4	4
07-01-29	10	45.00	42.00	62.00	10.00	45.00	55.00	4.00	1	1
07-01-29	11	45.00	54.00	62.00	14.00	45.00	44.00	4.00	16	16
07-01-29	12	42.00	40.00	62.00	18.00	45.00	54.00	4.00	0	0

Table 1. Continued

Date	Trans	Start latitude (deg/min)		Longitude (deg/min)		Stop latitude (deg/min)		Space (min. long.)	Total pups	Adj. pups
07-01-29	13	45.00	52.00	62.00	22.00	42.00	40.00	4.00	10	10
07-01-29	14	45.00	39.00	62.00	26.00	45.00	53.00	4.00	1	1
07-01-29	15	46.00	56.00	62.00	30.00	45.00	39.00	4.00	1	1
07-01-29	16	46.00	40.00	62.00	34.00	46.00	55.00	4.00	0	0
07-01-29	17	46.00	56.00	62.00	38.00	45.00	40.00	4.00	0	0
07-01-29	18	45.00	47.00	62.00	42.00	45.00	56.00	4.00	0	0
07-01-29	19	45.00	57.00	62.00	46.00	45.00	47.00	4.00	0	0
07-01-30	1	45.00	47.00	61.00	30.00	45.00	41.00	4.00	1	1
07-01-30	2	45.00	38.00	61.00	34.00	45.00	47.00	4.00	1	1
07-01-30	3	45.00	49.00	61.00	38.00	45.00	38.00	4.00	9	9
07-01-30	4	45.00	38.00	61.00	42.00	45.00	49.00	4.00	10	10
07-01-30	5	45.00	53.00	61.00	46.00	45.00	38.00	4.00	8	8
07-01-30	6	45.00	54.00	61.00	50.00	45.00	50.00	4.00	0	0
07-01-30	7	45.00	56.00	61.00	54.00	45.00	52.00	4.00	2	2
07-01-30	8	45.00	49.00	61.00	58.00	45.00	56.00	4.00	0	0
07-01-30	9	45.00	56.00	62.00	2.00	45.00	49.00	4.00	1	1
07-01-30	10	45.00	47.00	62.00	6.00	45.00	56.00	4.00	1	1
07-01-30	11	45.00	55.00	62.00	10.00	45.00	45.00	4.00	0	0
07-01-30	12	45.00	41.00	62.00	14.00	45.00	55.00	4.00	5	5
07-01-30	13	46.00	56.00	62.00	18.00	45.00	41.00	4.00	0	0
07-01-30	14	45.00	40.00	62.00	22.00	46.00	56.00	4.00	6	6
07-01-30	15	46.00	55.00	62.00	26.00	45.00	40.00	4.00	0	0
07-01-30	16	45.00	56.00	62.00	34.00	45.00	41.00	4.00	0	0
07-01-30	17	45.00	41.00	62.00	36.00	46.00	55.00	4.00	0	0
07-01-30	18	45.00	43.00	62.00	38.00	45.00	56.00	4.00	0	0
07-01-30	19	46.00	56.00	62.00	42.00	45.00	43.00	4.00	0	0

Table 2. Number of grey seal pups in different stages observed on the pack ice.

Stage	1	2	3	Total
2007-01-29	33	72	11	116
2007-01-22	7	0	1	8
2007-01-24	6	9	2	17
2007-01-28	14	143	6	163
2007-01-30	0	8	23	31
2007-02-04	21	121	147	289
2007-02-07	5	175	311	491
2007-02-09	5	57	122	184
2007-02-11		75	296	371

Table 3. Number of grey seal pups in different stages observed on island breeding colonies in the Gulf and on the eastern shore of Cape Breton Island and Nova Scotia.

	Date (yy/mm/dd)	Stage 1	Stage 2	Stage 3	Total
Henry Island	070110	138	10	0	148
	070122	50	484	441	975
	070129	12	61	148	221
	070205	1	52	306	359
	070209	0	35	165	200
	070211	0	1	77	78
Pictou Island	070111	52	1	0	
	070121	728	564	271	1563
	070126	1274	538	802	2614
	070130	11	427	785	1223
	070207	0	46	536	582
	070211	0	18	389	407
Amet Island	070111	21	209	25	255
	070121	4	295	277	576
	070126	0	46	113	159
	070210	0	0	7	7
Hay Island	070111	246	879	218	
	070118	58	380	536	974
	070131	0	28	165	193
	070201	0	13	161	174
Oak Island	070204	0	39	1086	
	070206	0	30	271	
	070210	0	8	107	

Table 4. Unadjusted systematic strip transect survey estimates, estimated proportion of pups, and final estimate after correcting the survey data for pupping for surveys in Hillsborough Bay and in Northumberland Strait flown over the ice in January 2007.

Date	Unadjusted estimate (SE)	Proportion pupped (SE)	Adjusted estimate
	'Old' Stage duration data from Bowen *et al.* 2003		
24-janv	1,292 (294)	0.345 (0.0832)	3,746 (1,243)
29-janv	3,475 (1,104)	0.678 (0.0684)	5,124 (1,707)
30-janv	2,273 (604)	0.737 (0.0613)	3,082 (858)
	'New' Stage duration data from Sable Island 2007		
24-janv	1,292 (294)	0.207 (0.0687)	6,249 (2,514)
29-janv	3,475 (1,104)	0.525 (0.0795)	6,613 (2,327)
30-janv	2,273 (604)	0.595 (0.0757)	3,819 (1,125)

Table 5a. Grey seals pup counts from eastern Cape Breton, and Eastern Shore islands based on the Old stage durations.

Date	Location	Count	Dead	Total	Average	Proportion of births	Adjusted count
11-01-07	Bowen's Ledge	24			24		
11-01-07	White Island	56			56		
28-01-07	White Island	7	82	89	89		
11-01-07	Hay Island	1357		1357	1357	0.492 (0.05)	2758 (280)
31-01-07	Hay Island	2653	105	2758	2678 (57)	0.995 (0.003)	2692 (57)
31-01-07	Hay Island	2578	90	2668		0.995 (0.003)	
01-02-07	Hay Island	2566	98	2664		0.996 (0.002)	
01-02-07	Hay Island	2528	96	2624		0.996 (0.002)	

Table 5b. Grey seals pup counts from the Gulf islands. The proportions presented are based on the Old stage durations.

Date	Location	Count	Dead	Total	Average	Proportion		Adjusted
21-01-07	Pictou Island	764		764	784 (43)	0.445 (0.078)		1762 (324)
21-01-07	Pictou Island	754		754				
21-01-07	Pictou Island	799	34	833				
26-01-07	Pictou Island	1728	16	1744	1738 (29)	0.821 (0.67)		2116 (176)
26-01-07	Pictou Island	1750	21	1771				
26-01-07	Pictou Island	1676	25	1701				
26-01-07	Pictou Island	1720	14	1734				
30-01-07	Pictou Island	2054	16	2070	2111 (58)	0.961 (.0278)		2195 (88)
30-01-07	Pictou Island	2133	19	2152				
11-01-07	Amet Island	270		270	270	0.446 (.0811)		606 (110)
21-01-07	Amet Island	299		299	305 (12)	0.935 (.0216)		326 (15)
21-01-07	Amet Island	297		297				
21-01-07	Amet Island	319		319				
26-01-07	Amet Island	248	46	294	308 (12)	0.990 (.0051)		311 (13)
26-01-07	Amet Island	278	44	322				
26-01-07	Amet Island	267	48	315				
26-01-07	Amet Island	270	33	303				
10-01-07	Henry Island	148		148	148	0.064 (.0634)		2294 (2256)
23-01-07	Henry Island	1417	15	1432	1419 (16)	0.726 (0.1001)		1953 (272)
23-01-07	Henry Island	1390	17	1407				
30-01-07	Henry Island	575	24	599[1]				
25-01-07	Dead man Island	351	36	387	351 (32)			
25-01-07	Dead man Island	325	16	341				
25-01-07	Dead man Island	326		326				
24-01-07	Margaree Island	2		2				
25-01-07	Margaree Island	6		6				
04-02-07	Oak Island	931	35	966	946 (21)		1	946 (21)
04-02-07	Oak Island	912	41	953				
04-02-07	Oak Island	886	46	932				
04-02-07	Oak Island	896	34	930				

[1] Not used in final estimate of number of pups on island because a storm had moved through and pups disappeared.

Table 6. Estimates of total non-Sable (Gulf) grey seal pup production in 2007 under different assumptions for the stage duration data.

Location	Estimate	SE
Old stages		
Gulf		
Ice	3563	652.5
Oak Island	946	21.4
Amet Island	318	9.7
Pictou Island	2157	76.2
Deadman Island	351	31.8
Henry Island	1953	272
Margaree Island	6	
Anticosti	10	
Kouchibouguac	3	
Total Gulf	9307	712
Eastern Shore		
Hay Island	2695	56.3
White Island	89	
Bowen's Ledge	24	
Noddy Island	135	
Flat Island	69	
Total Eastern shore	3012	56.3
Total non-Sable	**12319**	**714**
New stages		
Gulf		
Ice	4615	940
Oak Island	946	22
Amet Island	327	11
Pictou Island	2706	56
Deadman Island	351.3	31.8
Henry Island	2449	522
Margaree Island	6	
Anticosti	10	
Kouchibouguac	3	
Total Gulf	11413	1077
Eastern Shore		
Hay Island	2706	57
White Island	89	
Bowen's Ledge	24	
Noddy Island	135	
Flat Island	69	
Total Eastern shore	3023	57
Total non-Sable	**14436**	**1079**

Table 7. Estimates of non-Sable or Gulf grey seal pup production, from mark-recapture (M-R) and aerial surveys, rounded to the nearest 100. Standard errors are in brackets.

Year	Anticosti M-R[1]	Sable M-R[1]	Within season M-R study[2]	Aerial survey
1984	7,000 (1,200)	7,400 (1,400)		
1985	6,400 (900)	7,800 (1,700)		
1986	5,400 (700)	8,600 (2,800)		
1989	10,400 (3,200)	8,900 (2,100)	9,800 (1,000)	
1990	9,200 (2,700)	8,100 (900)	10,500(1,000)	
1996[3]				11,100 (1,300)
1997[3]				7,300 (800)
2000[3]				6,100 (900)
2004				15,600 (1,200)
2007				13,000 (600)[4]

[1] Hammill *et al.* 1998
[2] Myers *et al.* 1997
[3] Hammill *et al.* 2007.
[4] Average of estimated pup production values obtained from different stage duration estimates.

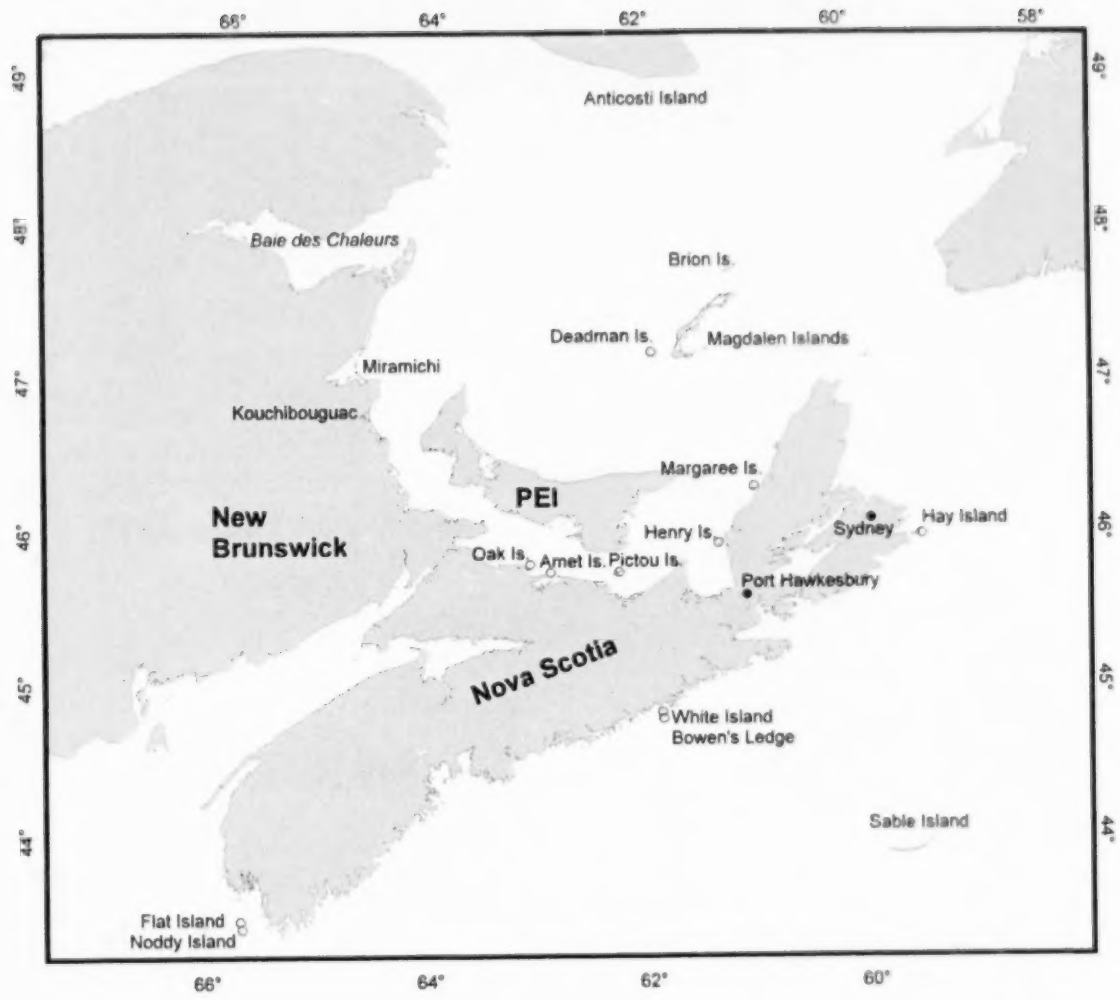

Figure 1. Map of study area.

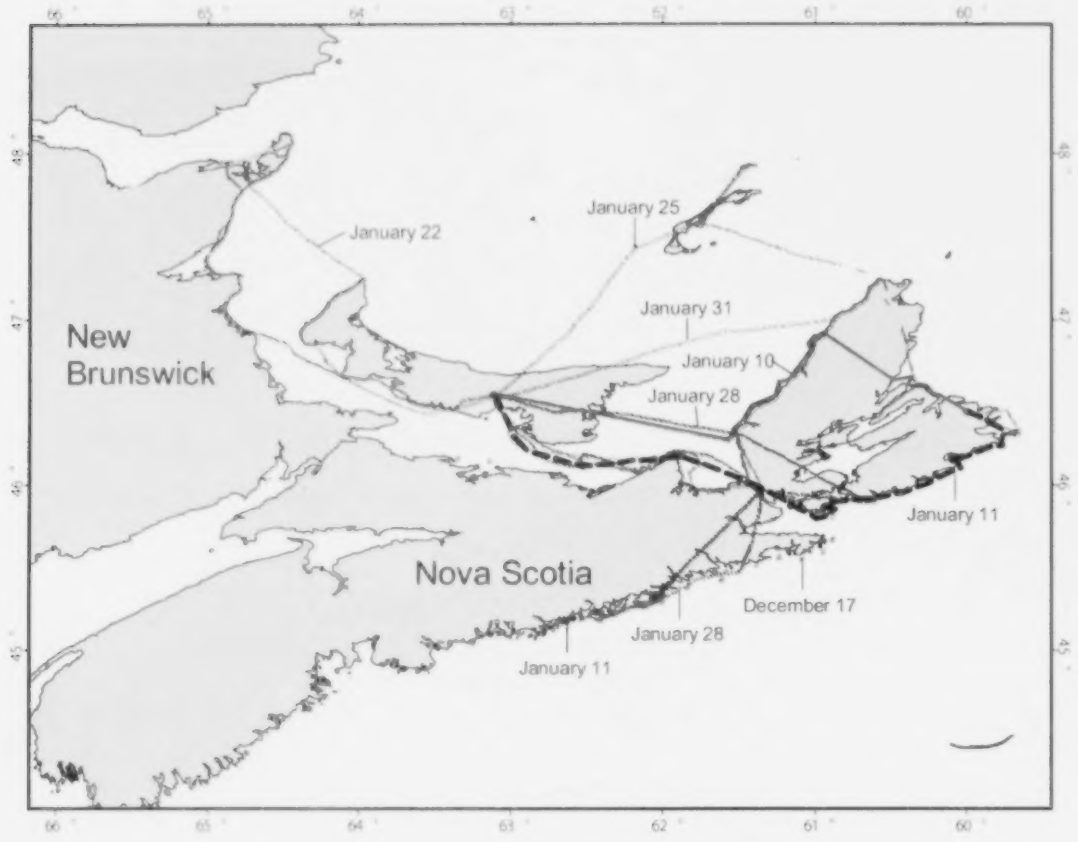

Figure 2. Reconnaissance surveys flown in the southern Gulf of St. Lawrence during December-February 2006-07.

Figure 3. Reconnaissance flights along south and part of west coasts of Newfoundland on 23 January 2007.

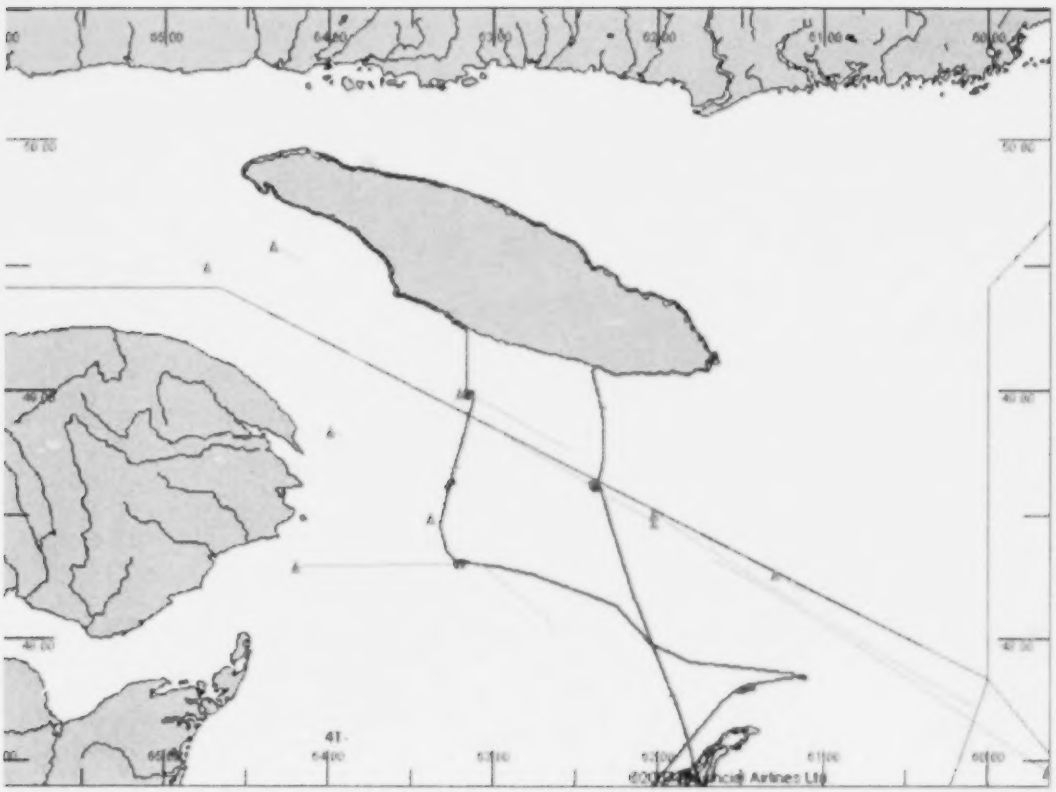

Figure 4. Reconnaissance flight around Anticosti Island on 13 February 2007.

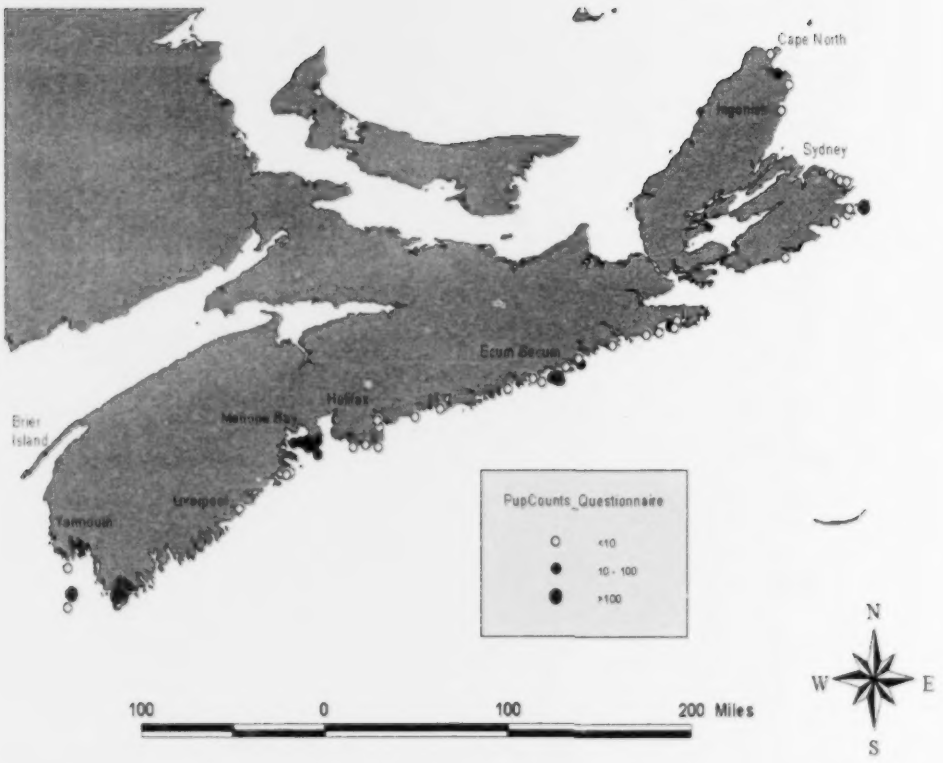

Figure 5. A map of the Nova Scotian shore showing the location and size of grey seal breeding colonies identified from the questionnaire.

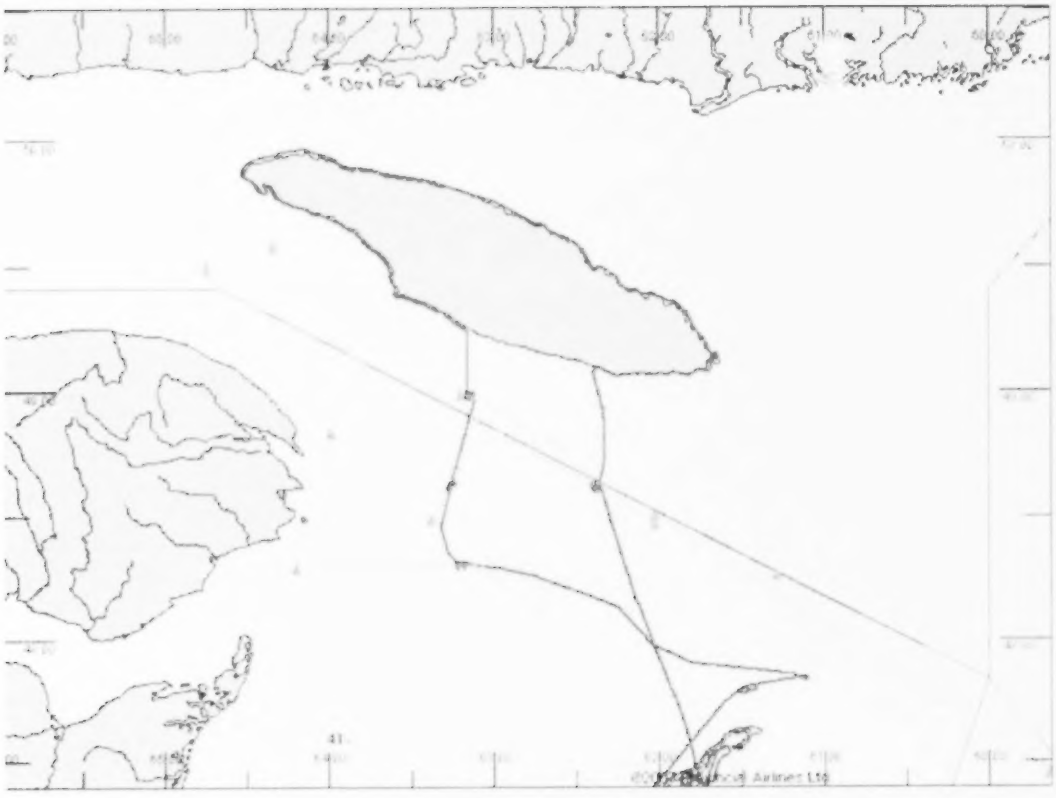

Figure 4. Reconnaissance flight around Anticosti Island on 13 February 2007.

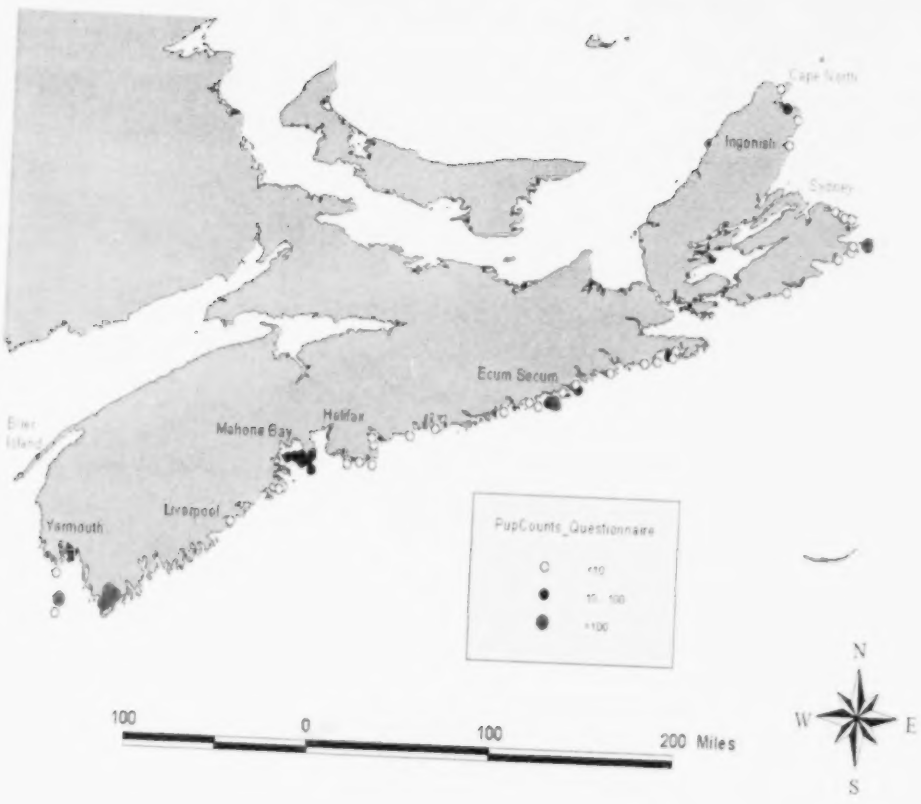

Figure 5. A map of the Nova Scotian shore showing the location and size of grey seal breeding colonies identified from the questionnaire.

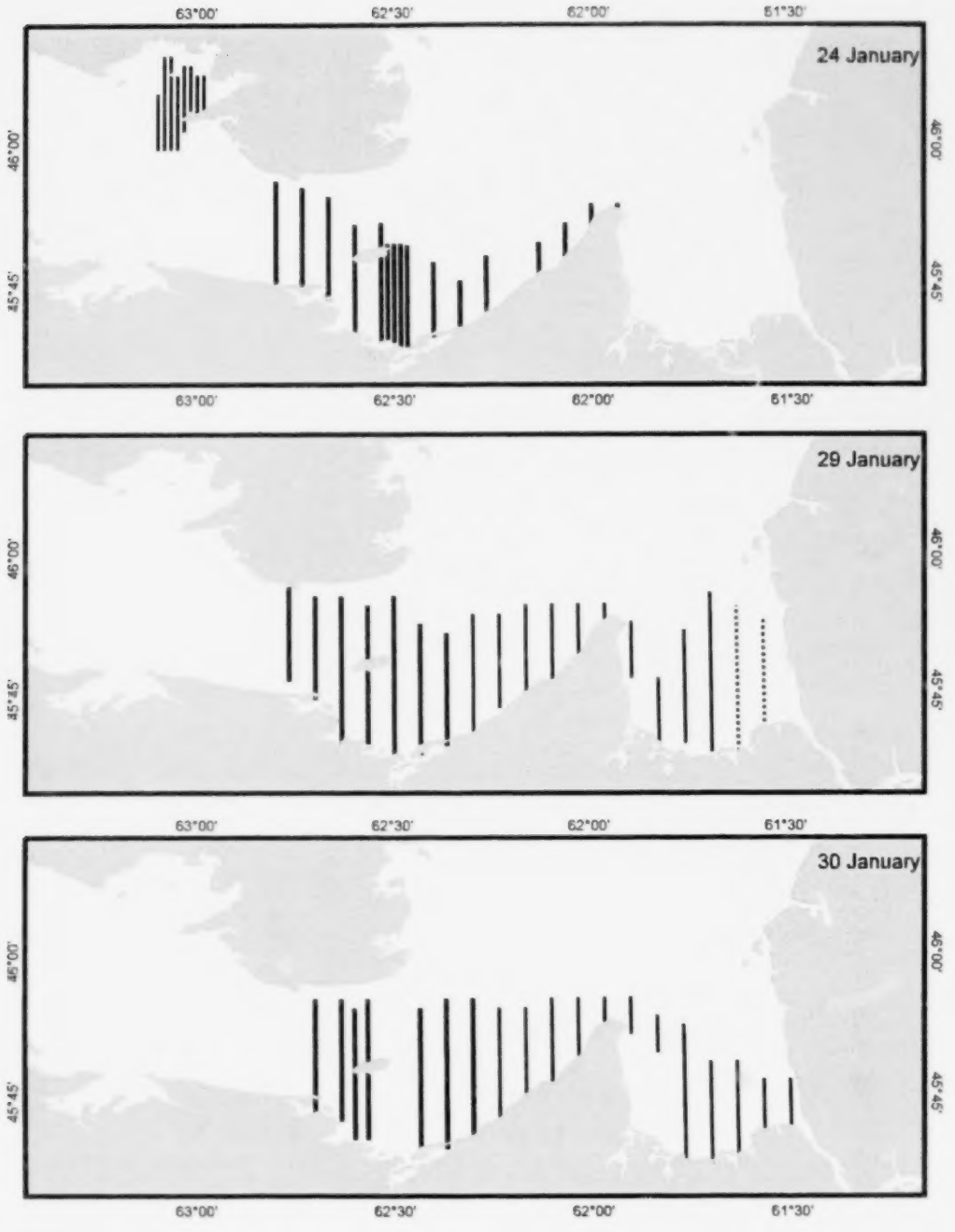

Figure 6. Location of transect lines flown over Hillsborough Bay and Northumberland Strait area in January 2007.

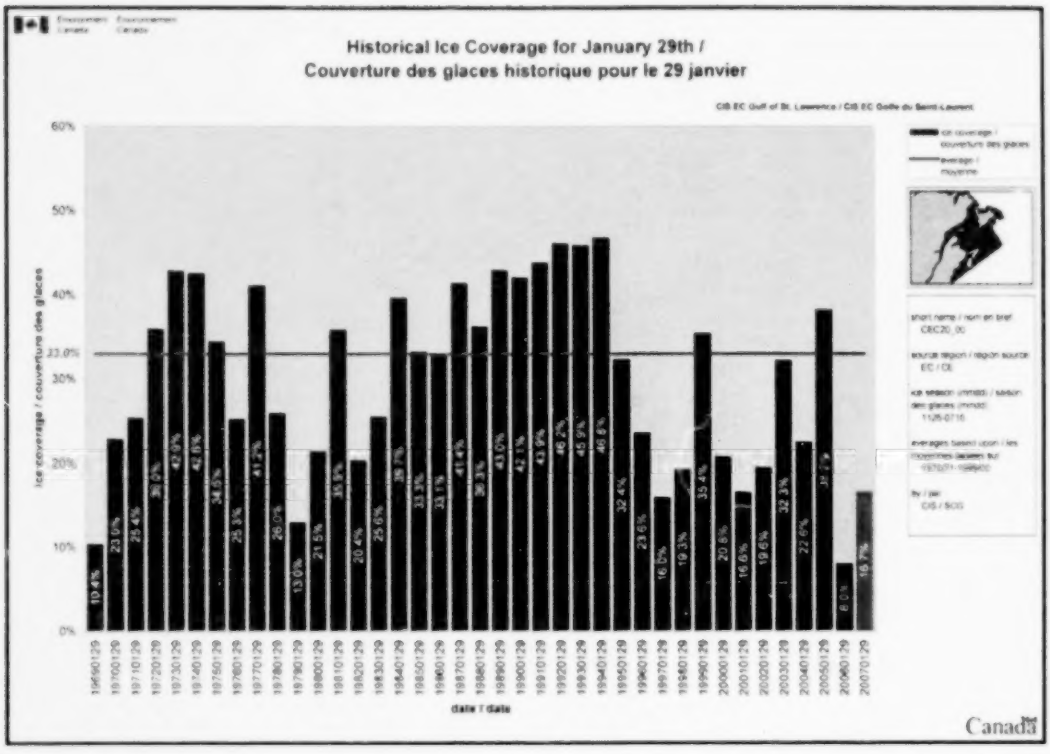
Historical Ice Coverage for January 29th /
Couverture des glaces historique pour le 29 janvier
Ice coverage / couverture des glaces
date / date
Canada

Figure 7. Ice cover in the Gulf of St Lawrence on 29 January from 1969-2007 (From Environment Canada: http://ice-glaces.ec.gc.ca/IceGraph/

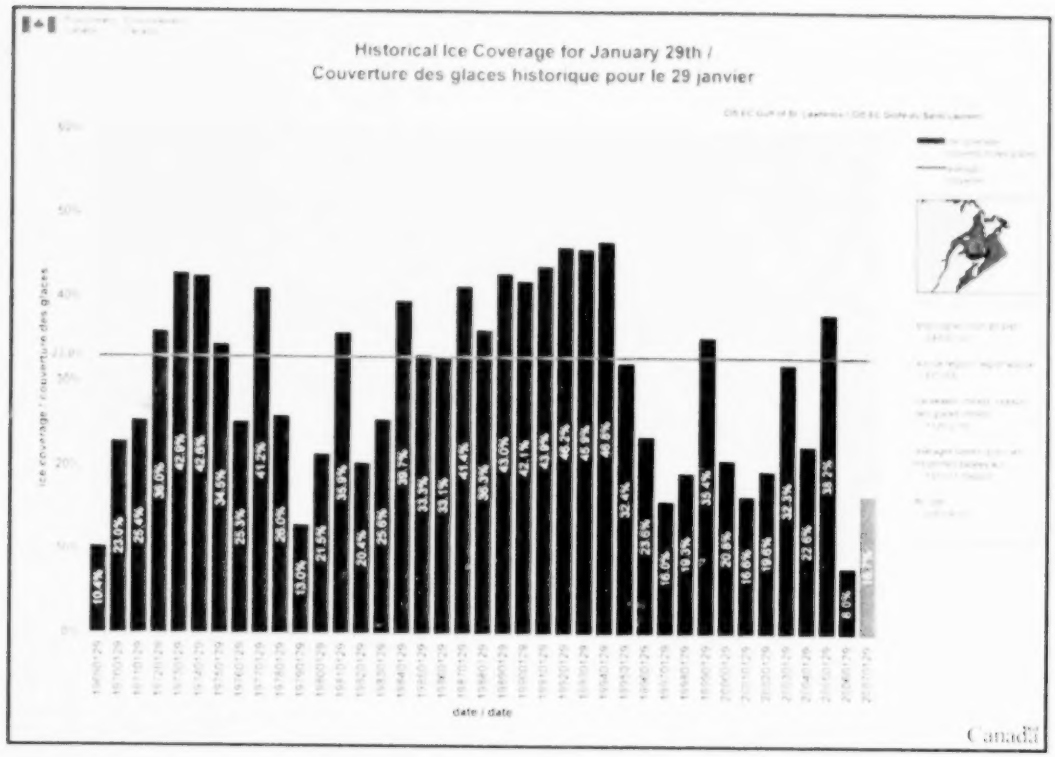

Figure 7. Ice cover in the Gulf of St Lawrence on 29 January from 1969-2007 (From Environment Canada: http://ice-glaces.ec.gc.ca/IceGraph/